ARL 62-415

A PORTABLE LOW LEVEL LIGHTMETER

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SOLID STATE PHYSICS RESEARCH LABORATORY

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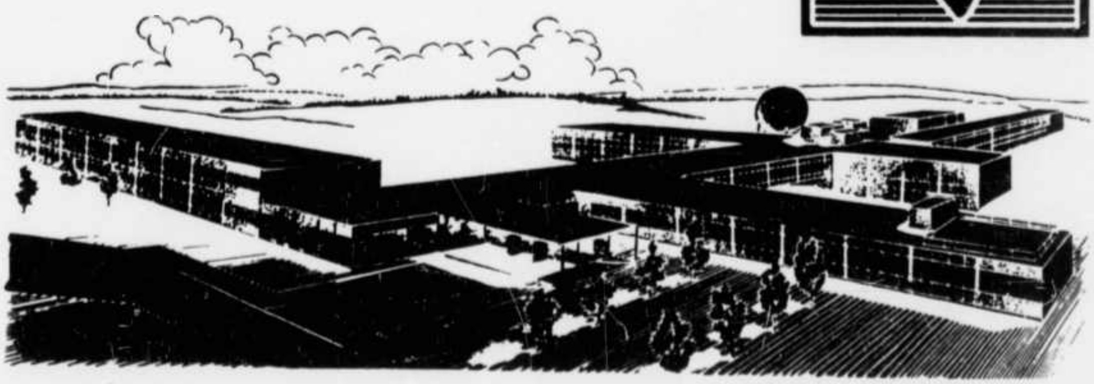

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FOREWORD

This technical documentary report was prepared by Mr. R. K. H. Gebel of the Solid State Physics Laboratory, Aeronautical Research Laboratories, Office of Aerospace Research, United States Air Force. The work reported herein was performed on Task 70827, " Light Amplification" of Project 7072, "Research on Quantum Nature of Light".

The author wishes to express his appreciation to Dr. John E. Clemens, former chief of tne Engineering Physics Research Branch, ARL, for his helpful suggestions and encouragement.

This technical report supersedes ARL 13, dated April 1961.

ABSTRACT

Explained herein is the operation and calibration of a portable low level lightmeter designed in connection with the work on the problems of light amplification. This lightmeter can be used to determine the light levels from as low as 10^{-8} foot-Lambert (ft-L).

INTRODUCTION

FACTUAL DATA

The purpose of the lightmeter (Figure 1) is to measure extremely low luminance levels (10^{-8} ft-L threshold). The lightmeter is fully portable and consists of four units.

The four units are:

Battery -	A 6-volt wet battery (4. 5 amp load) supplies the dc voltage for operation of a vibrator power supply.
Power Supply -	Converts the dc voltage to ac by a vibrator and steps up the ac voltage by a transformer. This unit supplies the operating voltage required by the pick-up unit and amplifier.
Pick-Up Unit -	Consists of a photomultiplier transducer and a Leitz 50 mm lens with an aperture of 1. 5 to 16.
Amplifier -	This unit is used for adjusting and calibrating the instrument, amplifying and measuring.

Lambert is defined as the C. G. S. unit of brightness equal to the brightness of a surface which is radiating or reflecting one lumen per square centimeter. A perfect diffusing surface emitting one lumen per square foot has a brightness of 1.076 millilamberts.

THEORY OF OPERATION

POWER SUPPLY

The 6-volt wet battery is connected to vibrator VB7. The vibrating reed of VB7 is connected in the circuit in such a manner that the battery voltage is first applied across one-half of the primary winding of the transformer T1, and then in the opposite direction across the other half. This induces an alternating voltage in the secondary of T1 having a value determined by the battery voltage and the transformer ratio. The vibrating reed has a resonant frequency in the order of 100-cycles, therefore, the associated transformer is designed for a 100-cycle fundamental. Buffer capacitor C1, in the secondary of T1, shapes the ac waveform, and controls voltages.

Switch S1 is an on-off switch that applies or removes dc voltage from the vibrator and, therefore, controls power to the rest of the equipment. Potentiometer P1 varies the voltage output of the battery and should be adjusted for optimum operating conditions of the photomultiplier tube. This voltage can be read from voltmeter V1, which is connected across the battery.

The voltages generated in the power supply are then fed to the pick-up unit (photomultiplier) and measurement unit (Figure 2).

PICK-UP UNIT

The pick-up unit consists of a 1P21 photomultiplier tube and a Leitz 50 mm lens with an aperture of 1.5 to 16. The anode supply voltage of the 1P21, derived from the power supply, is approximately 1000-volts peak-to-peak. The amplification and sensitivity of the 1P21 depends primarily on the voltage per dynode stage and the voltage between the last dynode stage, 9, and the anode.

Therefore, in order to cover the light range specified for the equipment the ac voltage applied to the photomultiplier must be controlled. This is accomplished by switch S4 in connection with resistors R7 and R8. When S4 is in position 1 (high amplification) the photomultiplier will cover a light range of approximately 10^{-3} to 10^{-8} ft-L. When S4 is in position II (low amplification) the voltage per dynode stage is less than position I since less amplification is required, and the light range covered in this position is 1 to 10^{-4} ft. L. The output of the pick-up unit is then fed to the measurement unit.

MEASUREMENT UNIT

The measurement unit is a bridge arrangement which uses the dual triode tube 12AV7. If no light falls on the photomultiplier tube, both sections of the 12AV7 will draw maximum current during the positive portion of the ac plate voltage on the 12AV7. If P1 and P2 are properly balanced, the instruments I1 and I2 will then show no current. If light falls on the photomultiplier cathode, ac pulses will be produced on the plate of the photomultiplier as a function of the ac supply voltages and these are then fed to section I of the 12AV7.

These pulses have to be in coincidence with the positive pulses on the plate of the 12AV7. A timing network, consisting of C2, C3 and L, assures proper timing of the grid and the plate pulses. It also determines, in connection with R2, the correct load resistance for the photomultiplier plate circuit. C4, C5, and C6 are responsible for the speed with which the meter responds. The switch S5 permits changing this response time. The relay RLS with the contacts S3 shunts automatically the highly sensitive instrument I1 if the current in the bridge path exceeds O. 1MA. This automatic switch arrangement is convenient if continuous readings are desired.

If the value on I2 drops to approximately two scale divisions, the switch opens and a full scale reading with 30 times higher accuracy can be taken from I1. Furthermore, it prevents automatically any damage through overloading on the instrument I1.

CALIBRATION OF THE LIGHTMETER

A calibrated precision foot-candle-meter, which uses a light sensitive selenium cell, was used as a standard. A nearly 100% diffuse reflecting screen was illuminated homogeneously with noon daylight. The illumination was measured with the foot-candle-meter, and the indication of the low level lightmeter was recorded with the lens directed toward the screen. During this measurement the well-calibrated lens (Leitz 50-mm, 1.5 to 16) was closed to an aperture of 16. After this step, the light level with an aperture of 1.5 which would give the same reading on the meter was calculated with the well-known formula:

$$\frac{\text{Existing light level}}{\text{Desired light level}} = \left(\frac{\text{Existing aperture}}{\text{Necessary aperture}}\right)^2$$

Now the lightmeter was opened to an aperture of 1.5, and the illumination of the diffuse reflecting screen was reduced until the lightmeter showed the first reading again. In this manner a second calibrated source of luminance was obtained at a lower level. Next the aperture was closed step by step, and each meter reading was recorded. For each meter reading the equivalent luminance level for an aperture of 1.5 was calculated by means of the lens formula. Now the entire procedure was repeated. The lens was opened to 1.5, and the lighting on the screen was adjusted to give the same meter reading which had been obtained with the previous calibrated luminance level at a lens opening of 16. This yielded a third calibrated luminance level. The aperture was then closed again, step by step, and each meter reading was recorded. For each meter reading the equivalent luminance level for an aperture of 1.5 was calculated by the lens formula. This entire process was repeated four times which gave enough calibration points to cover the entire light range from 1 to 10^{-8} ft-L. The instrument proved highly linear, so accurate calibration was possible without obtaining closely spaced calibration points (Figure 3).

CONCLUSIONS

The lightmeter was tested in open country and the performance was found satisfactory. Many different objects were measured with a night sky illumination of 3.5×10^{-5} foot-candles. The lowest value was found for wooded areas, with an average of approximately 4×10^{-7} ft.-L.

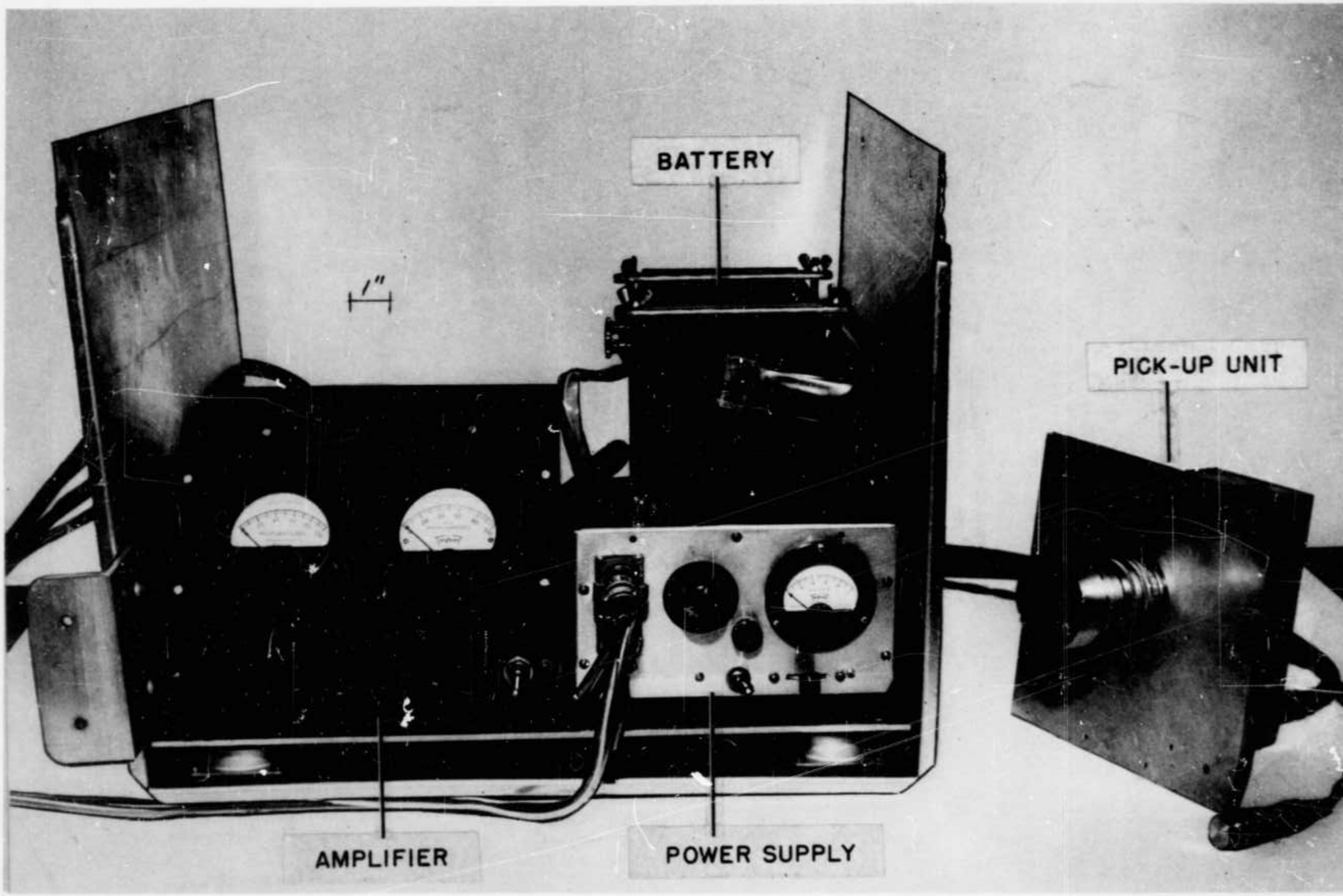

Figure 1. Low Level Lightmeter

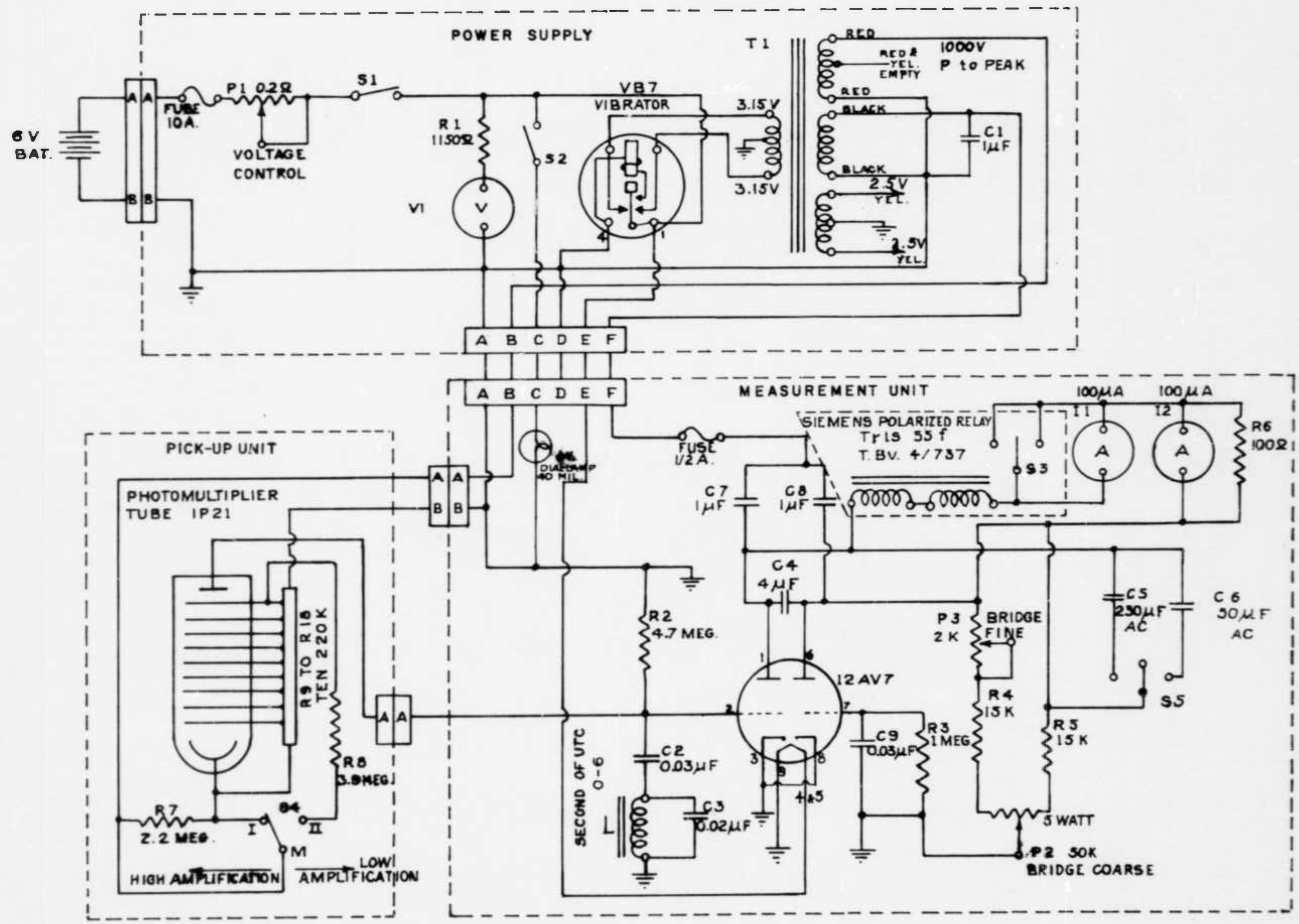

Figure 2. Schematic Diagram of Lightmeter.

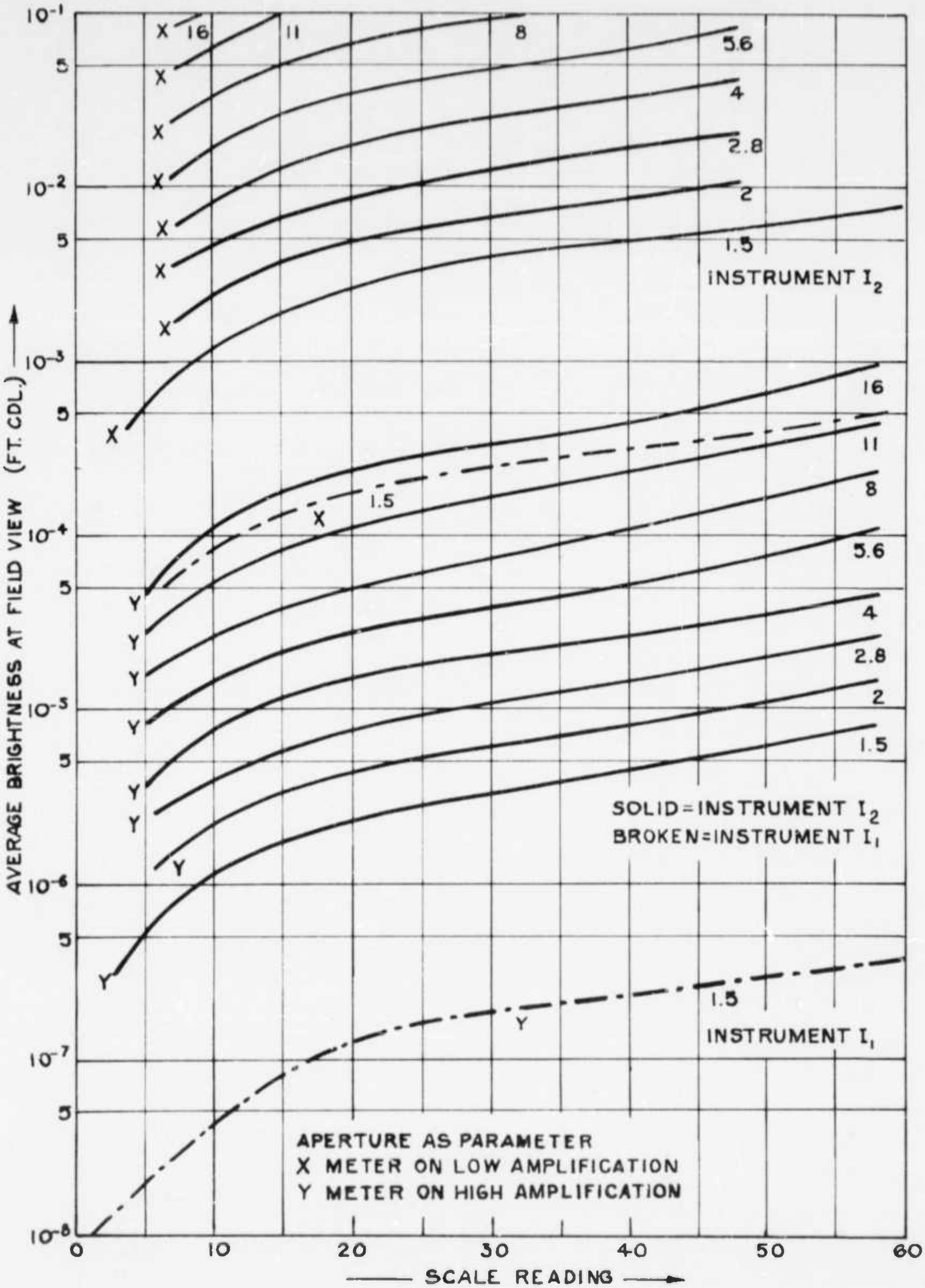

Figure 3. Calibration Characteristics of Low Level Lightmeter.

Aeronautical Research Laboratories, Wright-Patterson AFB, Ohio. A PORTABLE LOW LEVEL LIGHTMETER by R.K.H. GEBEL, Solid States Physics Research Laboratory, ARL. August 1962. 8 p. incl illus. (Project 7072; Task 70827) (ARL 62-415) Unclassified Report

Explained herein is the operation and calibration of a portable low level lightmeter designed in connection with work on the problem of light amplification. This light meter can be used to determine the light levels from as low as 10^{-8} foot-Lambert (ft-L).

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